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THE LAKE BIWA CANAL
AND ITS
HYDRO-ELECTRIC POWER.

THE MUNICIPAL ELECTRIC WORKS.

KYOTO, JAPAN.

1904.

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(THE MUNICIPAL ELECTRIC WORKS.)

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TOKYO.
Printed at the "Tokyo Tsukiji Type Foundry."

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THE MUNICIPAL ELECTRIC WORKS, KYOTO, JAPAN.

The construction of electric works by the municipality of Kyoto, challenges attention because of the fact that they represent one of the first examples of hydro-electric-power plants in the world. The plan and illustrative diagrams shown in connection with this descriptive text, will serve to give a general idea of the magnitude of the undertaking, together with a clearer understanding of certain details of the work.

The works are owned and managed by the municipal government of Kyoto, and supply electric light and power to all parts of the city. Kyoto has a population of 380,000, and it is one of the three principal cities in Japan: it is famous for its Fine Arts, for its old temples, and for the beautiful scenery of the mountains by which it is nearly encircled as in an amphitheatre.

The electric works, of which this monograph treats, are important not only for their magnitude but also, as has been said, because of their being the pioneer of such enterprises. Of a hundred electric-power stations now existing in Japan, one-half are hydro-electric plants which have followed, in their construction and management, the example set by the Kyoto electric power plant on the Lake Biwa Canal. There still remains, in various parts of the Empire, millions of horse-power in running water simply waiting for enterprising citizens to utilize them.

The rapid development in the use of water-power in the city of Kyoto has created a larger demand than the capacity of the existing plant is able to supply, and the construction of a new canal and the installation of an electric-power plant, having larger capacity than the present one, are expected to be commenced in the near future. The design of this new enterprise will be of the most recent and improved character, and when completed it is confidently assumed that it will be one of the best possible examples of a hydro-electric-power plant.

The Lake Biwa Canal not only supplies water-power to the present hydro-electric-power station, but it also affords a continuous line for boat navigation from Lake Biwa to tidewater in the bay of Osaka. Moreover, the canal yields a portion of its water for the purpose of irrigating extensive fields of rice in the agricultural districts adjacent to it. The municipality does not derive any substantial income from the electric plant, but it secures a certain indirect advantage for the city in that the plant supplies cheap electric light and motive power.

The general plan, which is shown in connection with this report, shows the Lake Biwa Canal, the hydro-electric-power station, the scheme of transmission wires, and longitudinal and cross sections of the canal; together with maps of Japan showing the situation of Lake Biwa and the course of the canal. The line of the new waterway, which is expected will be constructed in the near future parallel to the present canal, is also shown. The legend on the plan reads as follows:—

> Length of main canal, from Lake Biwa to the City of Kyoto, 7 miles, including 11253 feet of tunnels and 1820 feet of an inclined plane.
>
> Length of canal, from the City of Kyoto to the Town of Fushimi, 5½ miles.
>
> Length of branch canal, 5¼ miles.
>
> Capacity of main canal 300 cubic feet per second.
>
> Power station 115 × 138 feet with 19 dynamos having a total output of 1785 kilowatts.
>
> 5 lines of 36 inch pipes supply the power station with 250 cubic feet per second of water having 100 feet of effective head.
>
> Total length of power transmission wires 218 miles.
>
> Work on the canal was commenced in August 1885, the main and branch canals were completed in April 1890,

THE POWER STATION IN DECEMBER 1891, THE CANAL FROM KYOTO TO FUSHIMI IN SEPTEMBER 1894.

PROFESSOR, DOCTOR S. TANABE, M. E., BEING THE ENGINEER-IN-CHIEF.

THE CONSTRUCTION OF A NEW CANAL AND POWER PLANT, HAVING LARGER CAPACITY THAN THE PRESENT ONES, IS EXPECTED TO BE COMMENCED IN THE NEAR FUTURE.

Plate No. 1 shows Lake Biwa and the Intake of the Canal. The surface of this lake, the largest in Japan, is 280 feet above the sea and its area covers 400 square miles.

On the left of the entrance to the canal, there is a considerable section of reclaimed land, extending 1000 feet from the shore; this was made with the materials taken from the canal excavation and in boring the tunnel. There is a small pumping-station at the outer extremity of this reclaimed land. The pumps supply water for a part of the town of Otsu, on the shores of the lake, and are worked by electric motors, the current being supplied from the hydro-electric-power station, 6 miles distant.

Just between the second and third bridges from the lake shore, there is a regulating sluice which admits a constant flow of water into the canal of 300 cubic feet per second: at one side of the sluice is a lock which permits of boats passing from the lake to the canal, and vice versa, at any difference of level of water in lake and canal.

The main canal debouches into the river Kamo, in the city of Kyoto: it has two locks, an inclined plane, and three tunnels; open section of the canal connecting them. The difference in level between intake and outlet is 140 feet, of which 129 feet are over come by the inclined plane and one lock; the remaining 11 feet by the canal gradient, which varies from 1 in 2000 to 1 in 3000.

Plate No. 2 shows the lock at the intake, in the town of Otsu: the regulating sluice and the tow-path of the canal are not seen. The lock-gates are left open when the level of the lake is very low, as was the case when this picture was taken, but they are usually shut. Underneath the pony truss is seen the entrance to tunnel No. 1: it is 1½ miles in length, is the longest navigable tunnel in Japan, and is one of the rarest examples of this kind of work in the world.

It has a horse-shoe cross section, 16 feet wide and 14 feet high, providing for a depth of water of 6 feet. The average velocity of the water in the tunnel being 3.3 feet per second, the boots going down stream are simply sculled; while those going up are propelled by pulling on a wire-rope which is fixed to staples driven into the wall of the tunnel; there is, therefore, no tow-path in the tunnel.

The tunnel was constructed almost entirely by hand labour; the reasons for this being chiefly the frequent changes in the character of the rock and the cheap wages of miners. The annexed diagram of the tunnel work shows the geological nature of the rock and the progress of the boring.

Plate No. 3 shows a stretch of open canal skirting the hillsides between tunnels Nos. 1 and 2. The pictures was taken from a hill just over tunnel No. 2, looking eastward toward tunnel No. 1.

This stretch is 2¾ miles long, with a mean width of water surface of 29 feet and a depth of 5 feet; it has side slopes protected by rubble-stone pitching set in cement mortar in some places.

Tunnels Nos. 2 and 3 are near each other: they have a length of 411 feet and 2802 feet respectively, and the construction is the same as that of tunnel No. 1.

Plate No. 4 shows the inclined plane as seen from the drum house. The incline is 1820 feet in length, being the longest in the world, and connects canals that have a difference of 118 feet in level, the slope of the plane being 1 in 15. A railway of 8 feet 3 inches guage is laid with 75 lb. rails on wooden sleepers. A steel wire-rope of 4 inches circumference and 5000 feet in length, is wound seven times round a drum 12 feet in diameter, and the remainder stretches over 60 grooved pulleys, distributed all the way from the high-level canal, or upper pool, to the tail-race, or lower pool. To this wire-rope two, eight-wheel cradles are hitched; upon these cradles a 5 ton freight-boat, as well as 10 ton boat, go up or down, loaded or empty, in 12 minutes.

The drum is run by a 50 horse-power Sprague motor, energized by a direct current of 500 volts.

Plate No. 5 shows the outside of the power station, as seen from the northwest.

The house is 138 x 115 feet and is built of brick in excavated ground with the object of securing as great a head of water as possible. On the north side, a flight of granite steps leads down to the two main entrances. A tower on the central ridge of the roof is added to permit of 80 line-wires leaving the power house. There are seven lighting conductors placed on the roof, to prevent direct discharge of atmospheric electricity. Five iron pipes of 36 inches diameter each, with a total length of 6300 feet, supply the power station with 250 cubic feet of water per second; this has an effective head of a little over 100 feet and drives 20 Pelton water-wheels.

The water, after turning the wheels, flows into the tail-race through a discharge tunnel 12 feet wide and 10 feet high. The whirlpool, towards the right-hand side of the picture, shows the water rushing on its way through the discharge tunnel.

Plate Nos. 6 and 7 show the interior of the power station. On the right-hand side, along the brick wall, are switchboards for the different dynamos.

The details of the arrangement of water-wheels, dynamos, and switchboards, are represented on the annexed plan and sections: in which numbers are marked on the dynamos, corresponding to those of the following table.

Table Showing the Different Types of Dynamos.

No.	Maker.	Kilowatt.	Phase Cycle.	Voltage.	R. P. M.	Kind of work.	When installed.	Length of line in feet.	Length of line Wire in feet.
1	Thomson	70	Single phase 125	1000	1070	Lighting	Sept. 1892	8059	48354
2	Edison	80	Direct current.	500	650	Supplying power	Dec. 1890	23139	46278
3	Edison	80	Direct current.	500	650	Supplying power	Dec. 1890	31409	62818
4	Stanley	60	Two phase 133	2000	1000	Supplying power and arc lighting	Aug. 1894	126990	279487
5	General Electric	100	Direct current.	500	725	Electric Railway	May 1894	8610	40445
6	General Electric	100	Direct current.	500	700	Electric Railway	April 1895		
7	Thomson	60	Single phase 125	2000	1500	Lighting	June 1893	8059	16118
8	General Electric	150	Three phase 60	2000	600	Cotton spinning	Dec. 1896	8483	16966
9	General Electric	75	Direct current.	500	750	Supplying power	June 1895	8248	24744
10	Siemen and Halske	80	Three phase 50	2000	500	Cotton spinning	June 1896	8248	24744
11	General Electric	100	Direct current.	500	650	Silk spinning	June 1896	5379	25308
12	Stanley	80	Two phase 133	2000	1000	Lighting	April 1895	8059	32236
13	General Electric	250	Three phase 60	2000	450	Supplying power and lighting	June 1900	23800	112730
14	Siemen and Halske	80	Three phase 50	2000	500	Supplying power	Sept. 1895	33538	100614
15	Westing house	100	Direct current.	500	650	Ice making	March 1901	2206	4412
16	Siemen and Halske	80	Three phase 50	2000	500	Lake shore power and lighting	April 1896	7107	21321
17	General Electric	80	Three phase 60	2000	900	Weaving	June 1896	19231	110346
18	Siemen and Halske	80	Three phase 50	2000	500	Cigarette factory	Dec. 1896	12876	38628
19	Stanley	80	Two phase 133	2000	1000	Supplying power and lighting	June 1895	21145	147945

19 Dynomos—1785 Kilowatts { 7 dynamos 635 KW. Direct current.
{ 12 dynamos 1150 KW. Alternating current.

Total length of Line wires 218 miles.

Table Showing Different Types of Stationary Motors.

General Electric Company. 500V.		Siemen & Halske Three phase induction. 120V.		Stanley Electric Co. Two phase induction. 500V.		Thomson direct current. 500V.		Sprague direct current. 500V.		Edison direct current. 500V.		Crooker wheeler direct current. 500V.		Perret direct current. 500V.		Westinghouse Three phase induction. 200V.	
Quan.	Size. H.P.	Quan.	Size. B.P.	Quan.	Size. H.P.	Quan.	Size. H.P.	Quan.	Size. H.P.	Quan.	Size. H.P.	Quan.	Size. H.P.	Quan.	Size. H.P.	Quan.	Size. H.P.
1	1	1	4	2 of 1	2	3 of 1	3	1	0.5	1	1	1	0.5	1	1	1	10
1	1.5	6 of 5	30	2 of 1.5	3	2 of 1.5	3	3 of 1	3	2 of 1.5	3	1	1	1	1.6		
1	2	3 of 10	30	1	2	7	2	3 of 5	15	1	2	1	3	1	2		
2 of 10	20	2 of 15	30	2 of 3	6	3 of 3	24	3 of 10	30	2 of 3	6	1	3	3	4.6		
1	30	2 of 25	50	6 of 5	30	1	45	1	15	1	4	4	9.5				
1	40			2 of 10	20			1	50	1	4.5						
2 of 100	200	14	144	1	30	15	77			2 of 5	10						
9	294.5	2000V.		16	93			12	113.5	1	8						
Three phase induction. 220V.		2 of 95	190							1	30						
1	2	16	334							12	68.5						
1	7.5																
2 of 10	20																
2 of 15	30																
1	30																
7	87.5																
Three phase Syoronous. 2000V.																	
1	100																
1	200																
2	300																
18	684																

$$97 \text{ motors } 1394.1 \text{ H. P.} \begin{cases} 55 \text{ direct current } 567.6 \text{ H. P.} \\ 42 \text{ alternating current } 826.5 \text{ H. P.} \end{cases}$$

$$42 \text{ alternating current motors} \begin{cases} 40 \text{ induction } 526.5 \text{ H. P.} \\ 2 \text{ syncronous } 300 \text{ H. P.} \end{cases}$$

Besides these, there are atationary motors of 200 H. P. transmitting power for electric tramway, and the balance for far motor, arc and incandescent lighting.

Table Showing Use of Electric Power and Lights Snpplied. (Dec. 1903).

Purpose for which used.	Electric horse power.	Light (in H. P.)	Customers.
Rice mills	24.5	2.00	12
Weaving and spinning mills	262.0	56.56	10
Dry goods establishment	6.5	4.80	3
Vermicelli etc. factories	1.5	3.58	2
Whetstone works	5.0	0.0	1
Dyeing establishment	25.0	2.0	2
Metal foil works	10.0	2.5	1
Oil-presses	20.0	1.0	3
Hotels	21.0	38.16	5
Silk spinning mill	135.0	20.0	1
Soda water maker	3.0	0.0	1
Hospital	4.0	0.0	1
City arc lights	0.0	32.5	—City. 32 lamps
Telephone exchange	10.0	0.0	1
Powers and lights	100.0	1054.6	1
Electric railway	200.0	0.0	1
Sheetmetal roll mill	122.0	8.5	5
Printing-offices	19.77	19.335	5
Apothecaries	1.0	0.0	1
Fan	0.1	1.7	1
News paper offices	3.0	0.0	1
Machine-shops	15.25	1.75	5
Cotton-spinning mill	290.0	36.972	1
Cigarette maker	100.0	10.0	1
Cotton mill	7.0	0.0	1
Needle works	20.0	0.0	1
Theater	10.0	0.0	1
Restaurant	1.0	1.93	1
Roll press	2.0	0.0	1
Watch factory	8.0	0.5	1
Bath-house	3.0	7.5	1
Ice works	100.0	3.5	1
Incline	30.0	0.0	1
Others	3.0	0.0	1
	1562.62	1309.387	

Table Showing Water Supplied in Cubic feet per Second.

Purpose for which used.	Quantity.	Customers.
Rice mills	369.882	16
Cotton mill	5.0	1
Fire hydrants	5.2	3
Cotton spinnings mill	86.0	1
Wire-rolling mill	39.0	1
Ice works	1.0	1
	506.082	23

Plate No. 8 shows a corner pole of one of the trunklines. It is Hinoki, Japanese cypress, 15 inches in diameter at the top, and 60 feet long. It has 27 crossarms of Keyaki 5 in. × 5 in. × 6 ft., which carry 80 insulated wires from No. 2 B. S., up to 19 Strands of No. 12 in size.

All the crossarms that carry high tension circuits are painted red to distinguish them from those carrying low tension wires, which are left unpainted. The way the pole leans away from the corner must seem quite peculiar to those who are accustomed to see upirght iron-poles; but this manner of construction is chosen for an express purpose.

Insulators for high tension lines have three petticoats, and two shackles of double petticoats are set up in series in such a way as to insure the best line-insulation.

FINANCIAL FEATURE.

The initial cost of construction of the Lake Biwa Canal amounted to $ 700,393.09 U. S. Gold. That part of this investment which was in the form of public bonds, was paid back long since, and no deficit exists at the present time. Of the expense of $ 328,824.60 incurred for electric plant, a part has been repaid, leaving the investment, at the end of 1902, at $ 234,650.00. By the end of the present fiscal year, that sum should be reduced to $ 207,500.00; and as 70% of the net profit is set aside for the purpose of repaying the investors, while 3% is reserved as a maintenance fund, by the end of 1909 all the original investment should be repaired.

The rates charged to customers along constructed lines for electric supply are:—

For less than 1 H. P.	@ $65.50	per H. P. per annum.
„ between 1 & 5 „ „	@ $43.25	„ „ „ „ „
„ „ 5 „ 10 „ „	@ $35.50	„ „ „ „ „
„ „ 10 „ 20 „ „	@ $32.50	„ „ „ „ „
„ „ 20 „ 30 „ „	@ $30.00	„ „ „ „ „
„ „ 30 „ 50 „ „	@ $27.00	2 „ „ „ „
„ „ 50 „100 „ „	@ $24.00	„ „ „ „ „
„ more than 100 „ „	@ $21.75	„ „ „ „ „

These rates are for 12 hours daily use: the increase is 30% for 18 hours daily use, and 50% for 24 hours use.

For water power, such customers are charged:—

$98.00 per annum per cubic foot per second at an 80 feet head; at a lower head a proportional reduction is made.

For boat traffic: the charges are:—

5 ton boat	@ $12.50	per boat per annum.
10 „ „	@ $20.00	„ „ „ „
Passenger „	@ $15.00	„ „ „ „
Row „	@ $ 5.00	„ „ „ „

Tolls for passenger and row boats at Ke-age Incline $0.15 per boat.
„ „ „ „ „ „ „ Fushimi „ $0.075 „ „

Table Showing Annual Income, in U. S. Gold Dollars.

Year.	Electric Horse Powers supplied.	Income from Electric power.	Water powers supplied in cu. ft. per sec.	Income from Water power.	No. of trips by freight boats.	Income from freight boats.	No. of trips by passenger boats.	Income from passenger boats and from Miscelaneous sources.	Total Annual income.
1891	36	40.02	26	157.43	589	178.30	814	525.32	901.07
1892	173	1129.18	64	569.55	4176	884.50	8023	675.90	328.13
1893	337	4362.63	131	1240.92	7217	981.38	12540	1157.85	7742.78
1894	567	8911.10	221	1579.53	7133	1329.92	14552	3465.56	15286.11
1895	1028	17637.41	289	2704.82	12075	1643.60	30028	3216.26	25202.09
1896	1520	26580.12	404	4286.86	9122	1493.82	18941	2405.71	34766.51
1897	1914	39028.52	416	5836.35	14290	1963.30	20627	2501.51	49329,68
1898	1960	43428.20	416	6164.20	11718	1634.52	22028	2300.41	53527.33
1899	2209	48889.69	464	6815.07	13497	1986.17	21264	3710.92	61401.85
1900	2311	49973.64	501	7358.97	15487	2225.80	20750	4272.99	63831.40
1901	2223	59642.29	506	8640.95	15327	1974.18	20724	3661.66	73919.08
1992	2397	64166.15	505	8673.32	18901	1845.27	21025	9842.31	84526.05

THE PROPOSED NEW WATERWAY.

Surveys and plans have already been made, and it is confidently expected that the construction of a new canal and power plant, of larger capacity than the existing ones, will be commenced within a short time.

As it is desirable not to interfere with the working of the present system, it has been decided that it is easier and more economical to construct an independent waterway, almost paralleling the existing canal.

The intake of the new waterway is to be on the north of that of the present one. It is intended to protect it with reclaimed land, and to construct an independent regulating sluice for it.

As it is not purposed using this new waterway for navigation, the depth of water will be increased and the cross section reduced, so that a much greater volume of water will be carried than can be admitted into the present canal.

Of the total length of 5 miles, from the intake to the proposed site of the new power station, about three fourth is to be run by tunnelling or in a covered way, the slope being 1 in 2615, with a capacity of 550 cubic feet per second. To the north of the fourth tunnel of the present canal, where the new waterway joins it, the width and depth will be increased and a new intake for the new power station is to be made.

Four lines of pipes of 48 inches diameter, with a total length of 1650 feet, are to run four turbines of 1100 horse-power each, with a dynamo coupled direct onto each turbine axle: one pipe of the same diameter is to be provided for overflow.

Of the 550 cubic feet of water per second, 50 cubic feet per second is to be reserved for the future water supply of Kyoto city, and the remaining 500 cubic feet of water per second is to run the turbines.

SUIRIJIMUSHO

J. NAIKI
Mayor of the City of Kyoto

R. OTSUKI
Vice Mayor

K. SHOBAYASHI
Vice Mayor

H. SUMITOMO
Treasurer

KYOTO

DECEMBER

1903

S. SHIMOTSUMA
Director

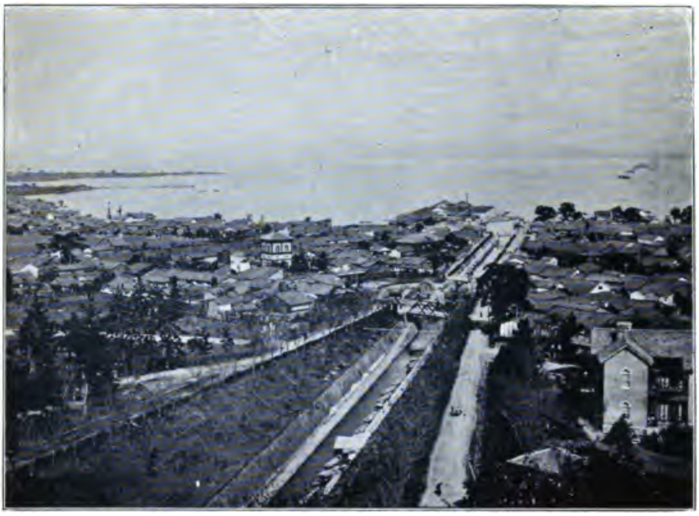
Y. KIMURA
Vice Director

G. E. KATO, E. E.
Chief-Eng.

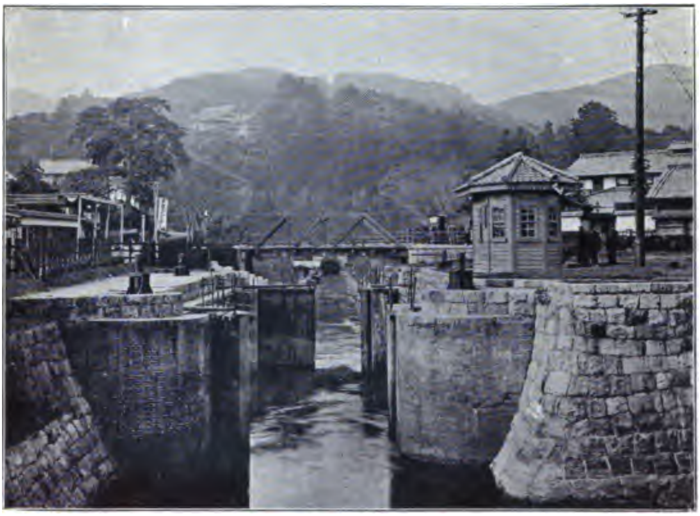
C. YAMADA
Engineer.

Dr. **S. TANABE, M. E.** *Consulting Engineer.*

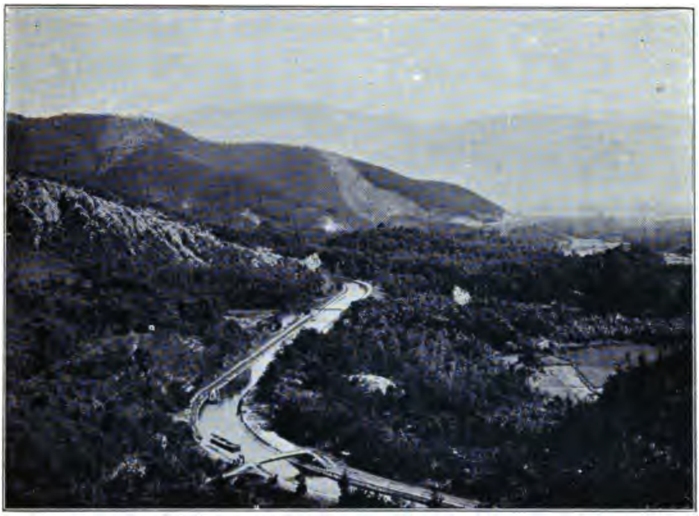
Baron **K. KITAGAKI** *was the proposer of the canal scheme.*



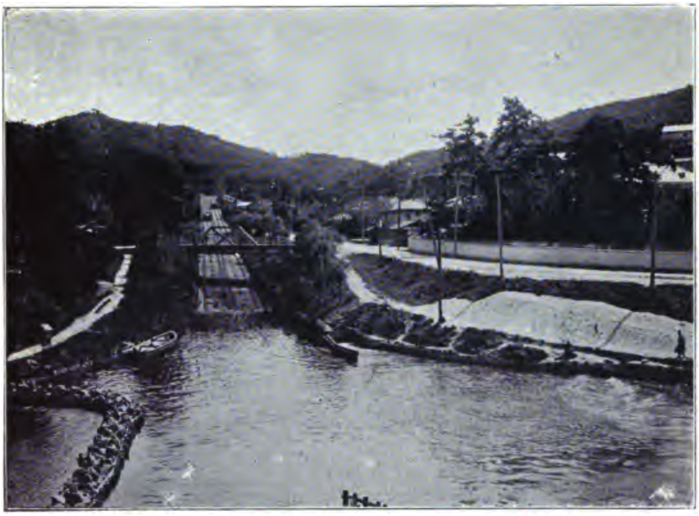
(1) The Lake Biwa and the Intake of the Canal.



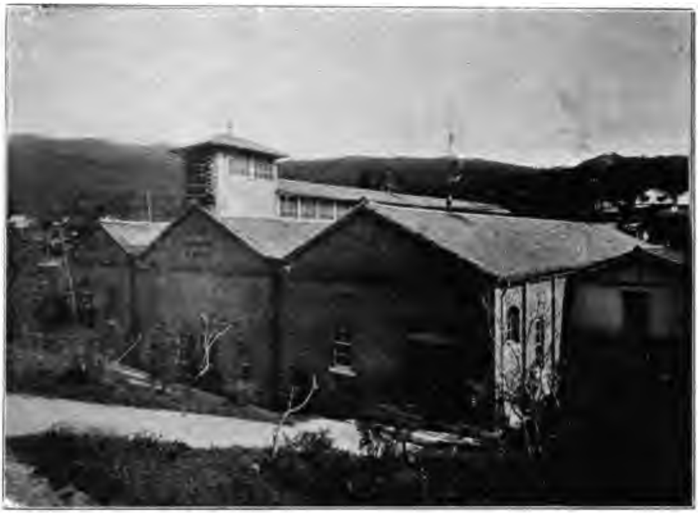
(2) The Lock at the Canal Intake, looking toward Tunnel No. 1.



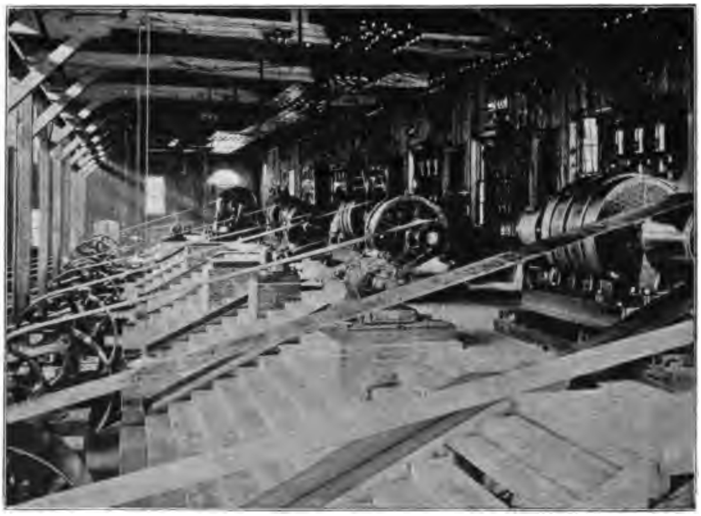
(3) The Open Canal between Tunnels No. 1 and No. 2.



(4) The Inclined Plane.

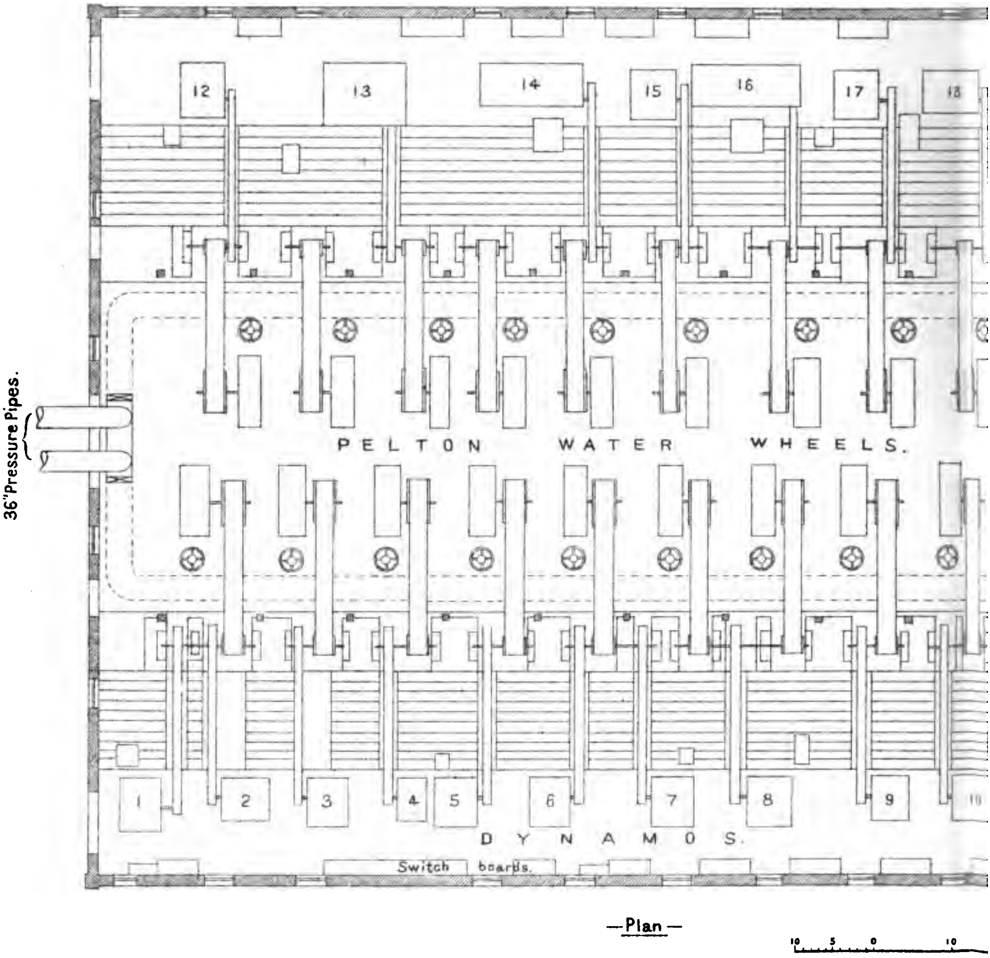


(5) The Hydro-electric Power Station, exterior appearance.

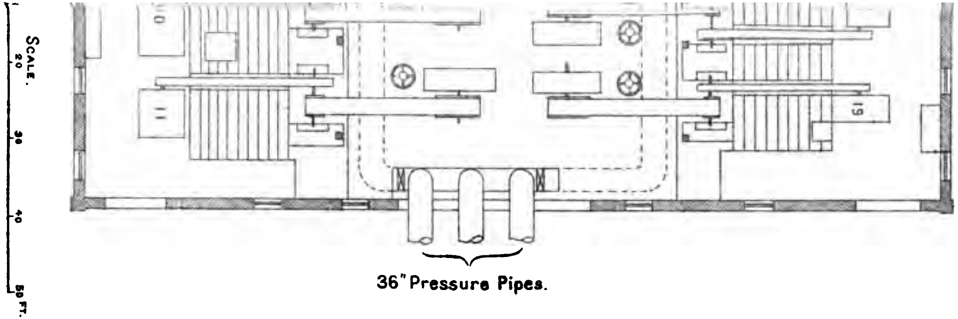


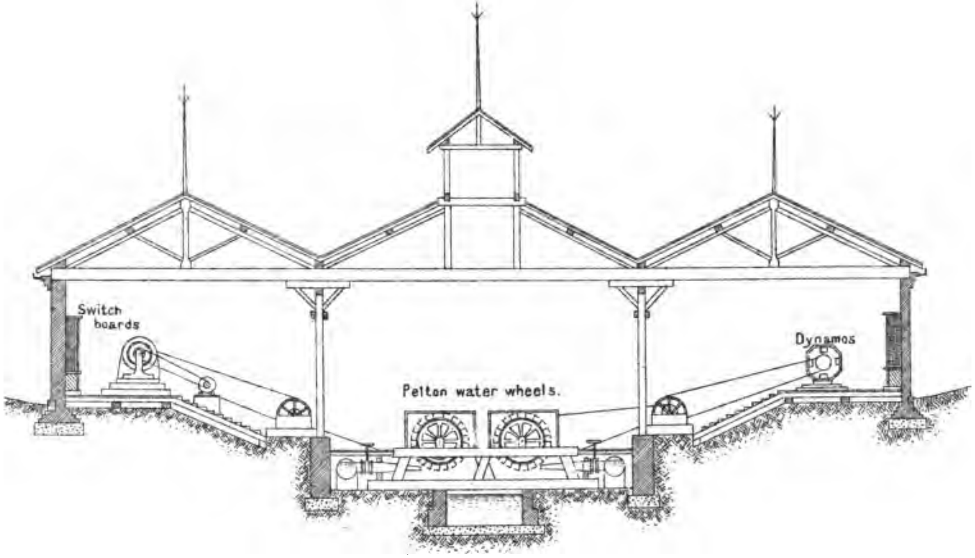
(6) The Hydro-electric Power Station, interior appearance.

HYDRO-ELECTRIC POWER STATION.



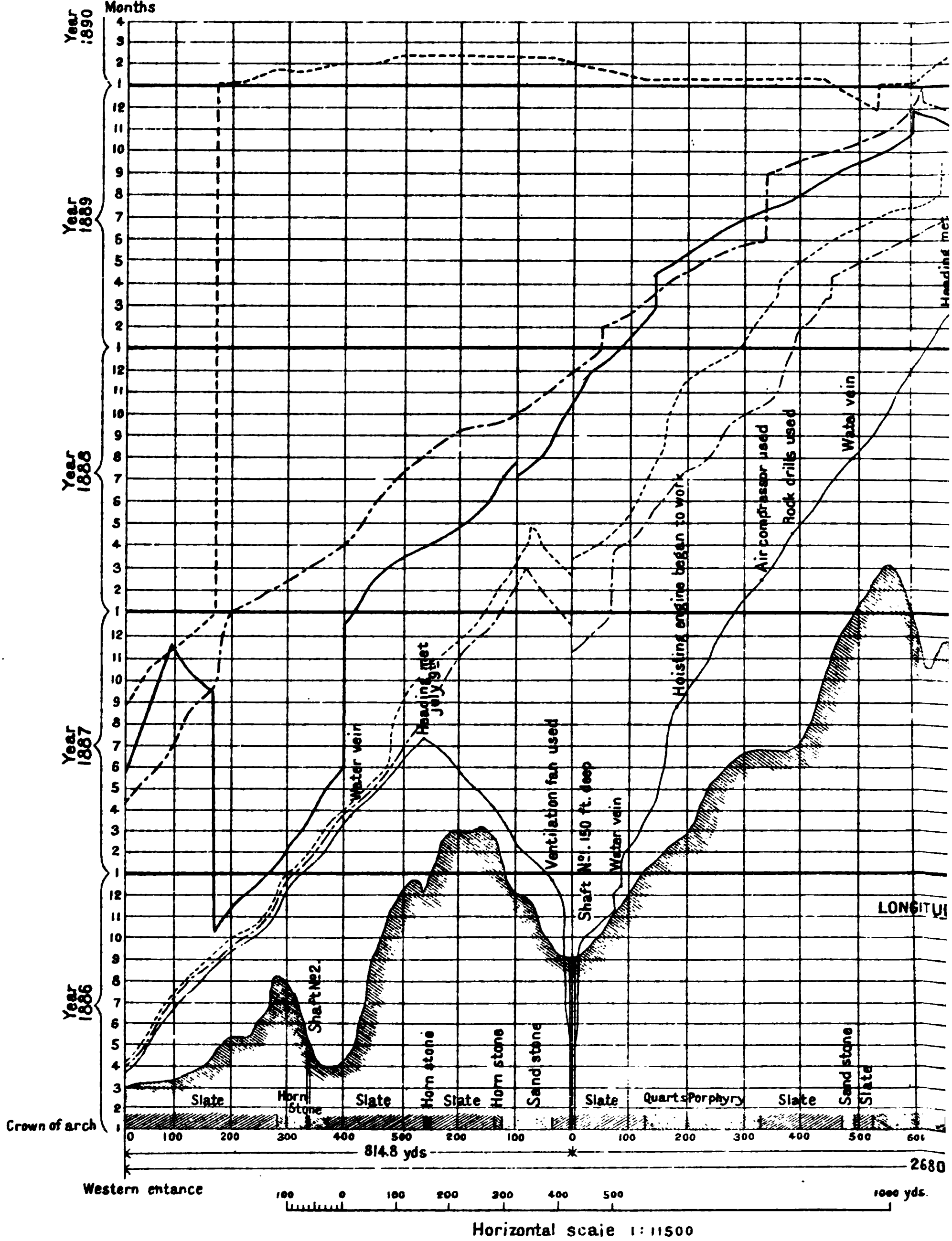
—Plan—



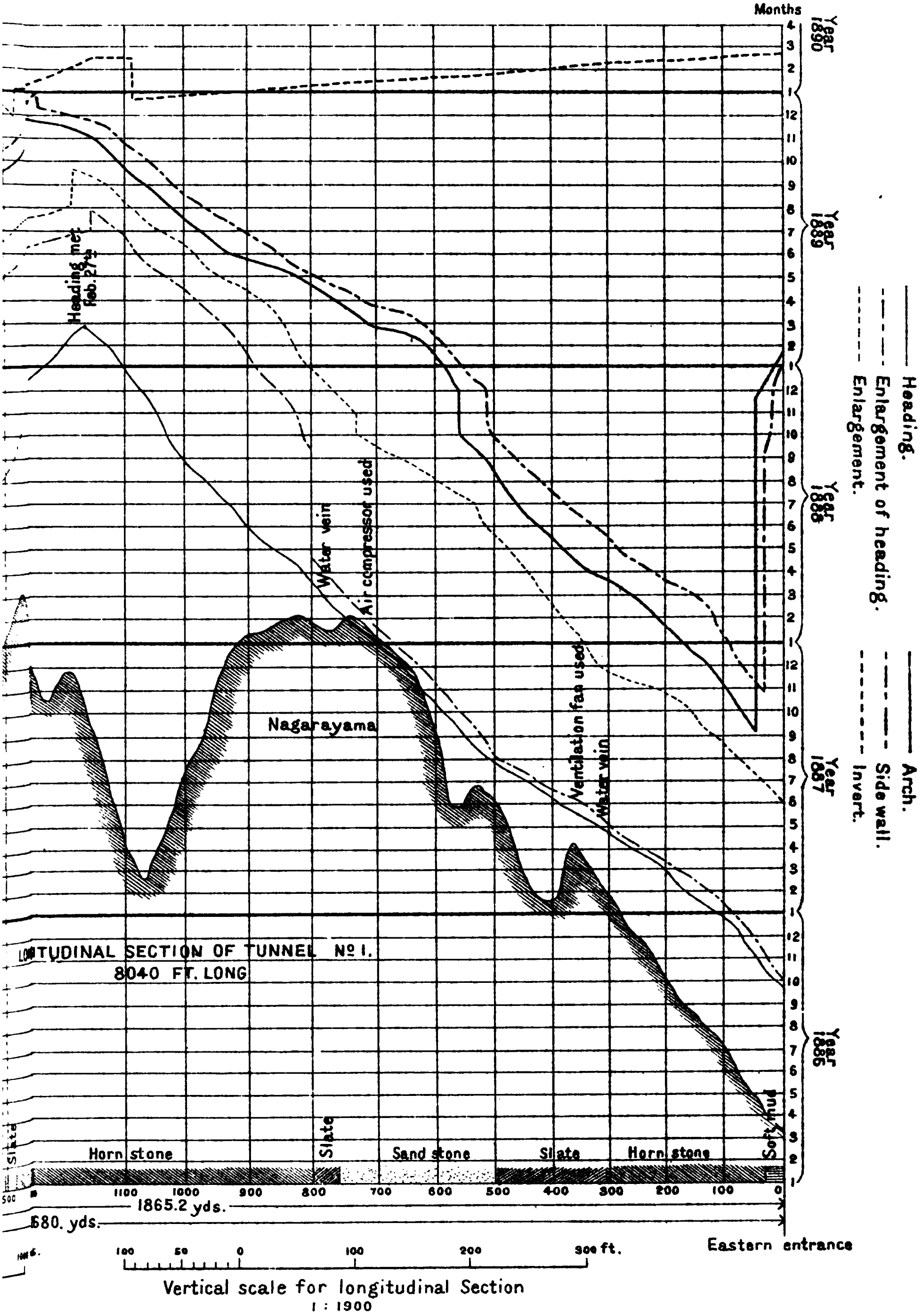


—Cross Section.—

PROGRESSIVE DIAGRAM FOR WORKS OF T



F TUNNEL Nº1. LAKE BIWA CANAL.



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